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ABSTRACT

Twelve hearing impaired children (aged 2-5 years) were trained to use a novel interactive microcomputer system with a special interface word keyboard which builds in perceptual salience, individualized vocabulary, animation, and color graphics in a two-person-plus computer communication system. Ss were taught to press keys with words and short statements drawn from the child's own central interests and favorite expressions. This action was possible because: (1) the keys are readily changeable; (2) new words and graphic representations of pictures can be quickly and efficiently entered in the computer; and (3) permanent disk storage allows instantaneous access to many printed words and accompanying color graphics. In using this system the Ss learned not only to read but, also, a special form of "writing"--creating his/her own printed messages on a TV. Results have demonstrated significant gains in word recognition and reading comprehension. (Author/CL)

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A CHILD-COMPUTER-TEACHER INTERACTIVE METHOD FOR TEACHING READING TO YOUNG DEAF CHILDREN

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Abstract

This research project involved an investigation of the effectiveness of microcomputer instruction for improving reading achievement in young deaf children.[1] The study incorporated the use of a portable microcomputer in the classroom to allow the child to initiate communication from the onset of instruction. Traditionally, children using computers have been required to respond to statements and questions, and their responses have been required to fall within a small range of acceptable answers. The approach used here instead provided a more flexible set of possibilities and gave the child a more active role.

Twelve children (age 2-5 years) attending The Pennsylvania School for the Deaf in Philadelphia participated in this phase of the study. These pupils were trained to use a novel interactive microcomputer system with a special interface word keyboard which builds in perceptual salience, individualized vocabulary, animation, and color graphics in a two-person-plus computer communication system. The child was taught to press keys with words and short statements drawn from the child's own central interests and favorite expressions. This action is possible because: (1) the keys are readily changeable; (2) new words and graphic representations of pictures can be quickly and efficiently entered in the computer; and (3) permanent disk storage allows instantaneous access to many printed words and accompanying color graphics. In using this system the child learned not only to read but, also, a special form of "writing"--creating his/her own printed messages on a TV. Results have demonstrated significant gains in word recognition and reading comprehension.

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Background

The availability of modern technology in the form of the computer has provided a new avenue for teaching deaf and hearing children alike (Hartley, 1978; Howe, 1978; Zinn, 1978). Although computer-assisted instruction has been used successfully with older deaf children, the situations in which it has been used tend to have been restricted, and certain communicative limitations have been imposed with this technology. Nickerson and Stevens (1973) reported on the development of a computer-based speech-training aid, involving pitch extraction and simultaneous visual display of vocal output. Culbertson (1974) utilized computer-assisted instruction (CAI) in teaching syllabus mathematics to deaf children in Texas. Sandals (1976) developed programs specifically for providing assistance with both linguistic and mathematical skills in deaf children from several Canadian schools. More recently, microcomputers have been adopted for use in microcomputer-assisted instruction in teaching written language skills to older deaf children (Arcanin & Zawolkow, 1980; Bates & Wilson, 1980; Ward & Rostron, to appear).

In reviewing these and other computer-assisted instruction projects, several drawbacks were noted. Much of the work described has involved large time-sharing machines, where the time available and range of additional facilities are limited. In such situations, the response time of the computer is dependent on the number of programs being processed. Average response times range between 10-20 seconds, thereby failing to provide immediate feedback to the child. Additionally, many of the computer programs have been designed to satisfy narrow curriculum requirements, rather than the linguistic needs of the deaf child acquiring language. Currently, deaf children using computers for learning language and reading are required primarily to respond to statements or questions. Such an approach

provides the child with no opportunity to initiate language nor to be an active catalyst in communication.

Another major criticism of current microcomputer usage with hearing-impaired children concerns the minimum amount of computer courseware developed to meet the specific needs of this population. A recent survey of microcomputer usage in schools for the deaf, conducted by the Educational Media Production Project for the Hearing-Impaired, found that 42% of the responding schools were using microcomputers (Harding & Tidball, 1982). Of the 158 schools surveyed, 120 responded, representing 45 states. Fifty schools indicated they have microcomputers. When asked whether they were considering the purchase or rental of additional microcomputers, 67 programs said yes, 41 responded no, and 12 made no response. The major use of the computers was for student instruction and use, taking 61% of the computer time, while the teaching of computer languages and programming occupied the computers another 16% of the time. When asked to cite the major problems with using microcomputers, the school's most common response was the lack of suitable software. Specific problems that were mentioned relating to available software included difficulty of the language and vocabulary, utilization of audio tones, difficulty in understanding and following directions, too much material on the screen at one time, and print size being too small.

In reviewing the literature at the project onset, the literature on reading in both deaf and hearing children we did not discover any studies which reported the use of microcomputers in teaching reading to children under the age of 6 years. One study by Moore (1966) reported the development and use of an automated typewriter for teaching reading and writing to preschool hearing children. This machine had the capability of talking and listening, accepting and responding to information, and presenting pictorial materials. It provided a "responsive" environment for learning--one in which exploration was encouraged. The children

were informed immediately about the consequences of their actions and it permitted them to make intensive use of their capabilities for discovering relations. The overall results of the study, although not carefully documented, suggested that some children can read, write, and take dictation, as well as compose their own stories before they enter the first grade.

Despite the newly advanced technology in the form of microcomputers which is now readily available to educators and the new insights into the cognitive and linguistic potential of young deaf children, deaf students continue to exhibit severe problems in learning how to read and write (Babbidge, 1965; Bonvillian, Nelson & Charrow, 1976; Furth, 1973; Gentile, 1972; Moores, 1978). The problem is not new--early in this century it was reported that the deaf encountered problems in learning to read (Pinter, 1918; Reamer, 1921). Vernon and Mendel (1971) indicated that 60% of all the deaf children in the United States were reading at a 5.3 reading level or below. Trybus and Karchmer (1977) examined the reading achievement of nearly 7,000 deaf students across the country and found them seriously deficient at all ages. The problem of teaching deaf children to read is not limited to the United States. Conrad (1977) presented data showing that the average deaf student in England and Wales (ages 15-16½) reads at a par with an 8-year-old hearing child. He cites observations that on completing school, deaf Swedish late adolescents are reading at about a fourth grade level. It is obvious that current approaches to reading instruction for deaf children have not been especially effective.

One of the reasons that many current approaches to reading instruction with deaf children have not been successful is that educators may have assumed that the problems of a limited vocabulary can be overcome simply by use of material written with that vocabulary in mind. Also, in many instances educators have neglected to adequately assess and describe how children use vocabulary words to formulate

sentences (i.e., syntactic abilities). Quigley, Power, and Steinkamp (1977) demonstrated that the age of acquisition of linguistic comprehension skills and control of common English syntactical forms is seriously delayed among the profoundly deaf. When the lack of understanding of base syntax is coupled with the restricted vocabulary skills of many deaf children, it becomes apparent that the major factor which differentiates the deaf from the hearing in reading is language insufficiency.

Recent advances in the field of psycholinguistics have shown that the child, hearing and deaf alike, enters the world predisposed to attend to and synthesize language-like input. A knowledge and comprehension of the language of the child's culture develops as the rules which define utterances are grasped and systematically internalized. This growth is achieved through the child's formulation of linguistic hypotheses (concerning meaning, grammatical correctness, etc.) which are then "tested" in actual communicative interactions with others. The processing of the linguistic information eventually develops into a knowledge of the rule system underlying language.

It appears that many deaf children have a rule-structured knowledge of language which deviates from "proper form" because of the poor quality of input information and available during the acquisition process, and not because of any inherent defect which renders rule acquisition impossible (Bonvillian, Charrow, & Nelson, 1973). The educator of the deaf in the United States is faced with the problem of making the English rule system of the hearing-impaired approximate more closely that of hearing users of English. In order to accomplish this objective it is apparent that deaf children must be placed in communicative situations which capitalize on active involvement in language manipulation and where information about language structure is presented in a form maximally assimilable by

children's learning strategies. Written words if presented in the proper way and proper contexts may be one part of an appropriate language learning environment.

Recent research suggests that the cognitive abilities of preschool children are often seriously underestimated. It is not uncommon for hearing children by age 5 to master two or more spoken languages (Lindholm, 1980) or to learn to read as well as speak (Smethurst, 1975; Soderbergh, 1977). Serving the same point that powerful language-learning capabilities exist in the young child are the few examples in the literature of hearing preschoolers who master both manual and oral communication (Holmes & Holmes, 1980; Prinz & Prinz, 1979, 1981).

Within the last two decades, psychologists and psycholinguists began to document the earlier cognitive and linguistic potential of both deaf and hearing preschool children (Bellugi, 1972; Furth, 1973, 1974). Recent reports on simultaneous and successive acquisition of language in a visual-gestural modality in both normal hearing and deaf children have demonstrated regular processes of language acquisition and an earlier linguistic awareness and capability than was heretofore imagined (Collins-Ahlgren, 1975; Prinz, 1981; Schlesinger & Meadow, 1972). Research findings affirmed the interdependence of cognition and language and the need to reorder priorities in reading instruction to take into account both underlying cognitive processes and language learning strategies. Additionally, studies of early reading instruction for preschool hearing children demonstrated that those children who were achieving more during the primary grades were those who had received training prior to the age of 6 (Durkin, 1964; McManna, 1964).

Nevertheless, deaf children of normal or exceptional intelligence frequently fail to find effective communication outlets for their cognitive abilities and consequently enter school years with low interpersonal communication skills and leave school years with low interpersonal communication skills and and low reading

and writing skills as compared with those of hearing children. The objective of the present project was to take advantage of the young deaf child's cognitive readiness by providing a strong start on reading and writing that will serve the child well, regardless of his/her primary mode of communication and how rapidly other communication skills are developing. The vehicle for this early beginning in reading is not simply a computer, but rather a complete, novel system that allows the child to initiate communication about any topic of interest to a skilled teacher by means of a combination of printed words and any already available language modes. From the outset of instruction, then, the child has the excitement of using printed words as another way of sharing ideas and feelings with others.

Method

The research was conducted at The Pennsylvania School for the Deaf in Philadelphia. During the initial phase of the study the computer system was assembled and tested and an initial set of information stored on disks. The "information set" included printed words and graphic representations of pictures to illustrate word meanings. The information set was developed on the basis of the children's performance on an initial language evaluation and baseline reading inventory. The information set, a type of specially designed software, allowed the teacher to formulate individualized instructional programs with the assistance of a computer programmer. Once the basic program had been developed, the teacher could independently help design courseware to further meet the needs of each child. Initial results indicated that all the children demonstrated major gains in word recognition and identification (Prinz, Nelson, & Stedt, 1982).

Subjects

The participants in the current phase of the study were 12 deaf children between the ages of 2 and 5. They all exhibited average or better intelligence as indicated by a performance scale of an accepted intelligence test. Only subjects with a severe-to-profound hearing impairment were included. A pure tone average (PTA) calculated for the better ear was examined. A pure tone average is equivalent to the average loss for the frequencies 500, 1000, and 2000 Hz (considered most important for speech reception). Subjects having a pure tone average loss in their better hearing ear of greater than 70 dB HTL, ANSI (1969), were selected. Additionally, all children were seen by an optometrist within 12 months prior to the beginning of the study and determined to have normal visual acuity and visual discrimination skills.

The child's mode or modes of communication were not a criterion for selection. An initial assessment was conducted of the child's basic communication skills including speech, speechreading, sign language, fingerspelling, and simultaneous communication (speech and sign). The communication assessment battery consisted of the following subtests.

First, an All Modes Imitation Test (consisting of sentences of varying length and grammatical complexity--designed to obtain information regarding negation, past, future, and present tense, and pluralization) was administered. The modes included speech only, American Sign Language, fingerspelling, simultaneous communication (speech plus sign language). The child's best mode or modes of communication were determined on the basis of performance on this measure.

Secondly, a modified version of The Peabody Picture Vocabulary Test (Dunn, 1965) was administered to assess receptive and productive vocabulary at the single word level in the child's best mode. The target lexical items were selected,

based on the following criteria: relative ease of lipreading ability, abstractness versus concreteness of the underlying semantic representation, degree of iconicity inherent in the sign, level of motoric difficulty in signing, and the familiarity of the item to deaf children between 2 and 5 years.

Additionally, the children were given a Sentence Imitation Test in their best mode of communication with items which increased in terms of length and grammatical complexity. Finally, an adapted version of the receptive portion of the Northwestern Syntax Screening Test (Lee, 1971) was used to evaluate the comprehension of grammatic and semantic relationships including locatives, present tense, pluralization, possessive case, wh-interrogatives, and the dative case.

During the first week of the study baseline measures of the child's reading abilities were completed. This procedure consisted of a reading recognition test including whole words and phrases. Based on this information and the above language measures, programs of instruction were developed for the children.

Equipment

The main equipment used in the project is the Apple II microcomputer system (+48K bytes) which is set up with a special, large interface keyboard with interchangeable overlays allowing more flexibility than a regular computer keyboard. This special piece of interface equipment, the EXPRESS-1 (Prentke Romich Company), allows the researcher to build in perceptual salience and individualized vocabulary for the keys that the child or teacher presses to activate animation and color graphics in a two-person-plus computer communication system. The use of a standard microcomputer by itself is typically difficult with small children because of the small size of the keys, the restriction to single letters rather than words on keys, and the limited output that a child can produce on the computer. The EXPRESS-1 provides large keys which allow whole words (or

pictures) to appear directly on the keys in sizes appropriate for beginning readers, and which are easy for the child to activate. Perceptually, the symbols are easier to distinguish than those on the smaller standard size typewriter keyboard which is provided on the Apple II computer. The microcomputer built into the EXPRESS-1 enables the user to program information (letters, words, phrases) at 114 locations on a matrix display. Also, it may be adapted for use with beginning readers by using pictures or graphic representations of signs. In this instance, when the child makes a selection of a picture or sign, the corresponding word or phrase as programmed is printed on the printer and/or large color monitor connected to the Apple II microcomputer unit. In this way, the EXPRESS-1 may also serve as a data entry terminal for the Apple II with computer instructions programmed by the user at one of four program levels and at various locations on the keyboard. Between 1 and 16 characters can be programmed at each location and the response rate can be adjusted to accommodate the information processing needs of each child. Additionally, the computer displays its output in either regular or enlarged print as well as in graphics on a larger color television monitor compared to the display typically employed with an instructional computer.

Courseware

As part of the current phase of the research, a software package was developed consisting of two different but compatible reading/language programs: the OMEGA and ALPHA series. Both the OMEGA and ALPHA programs each consist of eight different lessons designed to assist hearing-impaired students who are just beginning to read. Whole-word overlays for the EXPRESS Unit correspond to each OMEGA and ALPHA lesson. The focus of the OMEGA series is to develop a basic reading and "writing" vocabulary, and the ability to create simple phrases using this vocabulary. The ALPHA series is designed to allow the student to expand

his/her existing reading vocabulary to create more complex sentences. In both programs, the computer displays items in the form of printed words, animated pictures, and optional animated graphic representations of manual signs.

In this phase of the study, the computer system was set up in a room adjacent to the lower school classrooms at the school for the deaf. Each child worked for one or two daily sessions of 10-15 minutes each, well separated by other educational activities. The set of words, pictures, and graphics employed were gradually introduced, and the set was adjusted to reflect the child's vocabulary and interests. During this phase of instruction heavy redundancy was built into the instructional sessions. The system allowed the child to press keys which have words and/or pictures on them. On the key a child presses for "flower," for example, beside the word there might also appear a small picture. Similarly, the computer display monitor would show both word and picture, and where appropriate would also display a manual sign that the child already had learned.

The particular words used initially were all drawn from the child's own central interests and instructional objectives. This procedure was possible because the keys were readily changeable, because new words could be rapidly entered in the computer, and because permanent disk storage allows nearly instantaneous access to thousands of printed words and accompanying color graphics. When the child pressed the appropriate word or sequence of words, the computer responded accordingly. For example, suppose the child pressed the keys for "dog running." At this point, the television monitor would typically display both the printed words and redundant pictorial information. In addition, the teacher had the option of requesting more information or commenting on the child's message. This procedure could be done, for example, by asking the child if she/he wants to see a big dog or a small dog or by telling the child something else about the dog--again with display of appropriate print and graphics. This procedure also served to

create an atmosphere where the child actually initiated and used printed information in an active, interactional, and pragmatic manner to exchange messages with another person.

Reading Instructional Approach

For the younger children and beginning readers an associational approach was employed. The child was introduced to a series of 5-10 new words taken from the child's own interests and vocabulary that was central to classroom instruction. The child was initially shown pictures of objects and actions on the television monitor and asked to locate the corresponding printed word and/or graphic representation of the sign on the EXPRESS keyboard. After the child could successfully recognize the word, he was instructed how to read it by comparing it with other words on the EXPRESS Unit and selecting it from among those words. As the child progressed through each lesson, he/she received positive feedback and reinforcement from the microcomputer as well as praise and encouragement from the teacher.

For the special keyboard (EXPRESS), as each child progressed, the available lexicon of prelabeled keys continued to expand and even though the number of word keys available at one time was limited to 114, the research assistant could change keys (overlays) rapidly within sessions and thereby permit a very large total vocabulary to be incorporated into the system.

For those children who were at an intermediate level, the microcomputer presented a list of 8 to 10 nouns (e.g., boy, girl, dog, etc.) from which the child selected one on the EXPRESS keyboard. When she/he had selected a noun, the list disappeared and a large colorful drawing (captioned with the noun at the bottom of the screen) appeared, illustrating the selected word. Immediately another list appeared containing verbs (e.g., jumps, runs, throws, etc.). Selecting a verb then animated the graphic figures on the screen, and the animated sequence was captioned on the screen with a two-word sentence. This procedure was

repeated and expanded for older and more advanced language learners to allow for the generation and processing of more complex grammatical and semantic constructions of 3, 4, 5, and more words in length.

At these advanced levels, the children were reading and formulating multi-word sentences on the microcomputer in a variety of ways. One variation showed the child an animated sequence and the child then selected from the EXPRESS keyboard a full sentence--e.g., "The dogs chase the rabbit." The child was also able to first construct a sentence and then see the animated sequence to illustrate it. The OMEGA and ALPHA Language/Reading series was used to develop basic competence in interactive reading and writing instruction. The detailed instructional procedures used with these programs are described in the Appendix.

The child's oral and manual skills (and any writing/printing skills) were also tapped by the teacher in the process of instruction, so that the child learned to communicate about the computer-assisted material and learned to flexibly extend the new reading knowledge and vocabulary beyond the computer. For example, with a child who had good language skills in at least one modality, part of the instructional effort emphasized each of the following procedural sequences: child said or signed a message, and teacher placed the same message in print on the screen; the screen displayed a new message in print, and the child said or signed the message in response; the teacher directly asked the child a question, and the child used the EXPRESS to answer in appropriate printed words.

Results

The children's progress in the use of the novel system was formally evaluated both from the printers attached to the Apple II and the EXPRESS-1 keyboard and the lessons saved on the microcomputer diskettes. The exact records of child key presses, teacher key presses, and the displays generated on the television were

available for analysis. In all variations, highly reliable data in the form of printed records of the child's progress on selected days was obtained from the printer. In addition, at the completion of each instructional session the teacher filled out a "Daily Apple/EXPRESS Record Form" and attached it to the printer records of the child's progress. Teacher comments regarding the child's performance during any session were either entered on the Daily Record Form or typed directly onto the printed record via the printer connected to the Apple microcomputer and the EXPRESS.

A preliminary analysis of the data after 10 weeks of reading instruction using the microcomputer revealed that all of the children between the ages of 2 and 5 years demonstrated significant gains in word recognition and reading. The percentage of improvement in word recognition from pretest to posttest on OMEGA Lessons 1-3 for each child participating in the project is summarized in Table 1. The overall mean percentage of improvement for the 2- to 3-year-old children over 10 weeks was 31%. The overall percentage of improvement for the 4- and 5-year-old children for the same time period was 19%.

Because communication and language skills generally could possibly be facilitated by this project's interactive approach to teaching reading, the subjects were administered a Sentence Imitation Test prior to and following microcomputer reading instruction. This test measured imitative responses in the children's best communicative mode (i.e., ASL or simultaneous communication). The results (summarized in Table 2) indicated that the overall mean percentage of improvement for the 2- to 3-year-old children was 42.3% and 50.3% of the 4- to 5-year-olds. This finding is tentative and exploratory but is at least encouraging to the idea that preschool reading instructional programs could serve to enhance not only reading but broader aspects of language skills.

Table 1

Percentage Correct and Percent of Improvement on a Word Recognition-Reading Procedure

			Omega Lesson 1			Omega Lesson 2			Omega Lesson 3			
Subject	Age	Sex	Pre	Post	% Improvement	Pre	Post	% Improvement	Pre	Post	% Improvement	Overall Mean % Improvement Lessons 1-3
1	2	M	50%	100%	50%	71%	100%	29%	60%	87%	27%	36%
2	2	F	100%	100%	---	71%	83%	12%	43%	64%	21%	17%
3	2	F	43%	80%	37%	100%	100%	---	56%	100%	44%	41%
4	3	M	87%	100%	13%	83%	100%	17%	57%	100%	43%	25%
5	3	M	87%	95%	8%	100%	100%	---	69%	100%	31%	20%
6	3	M	67%	100%	33%	100%	100%	---	0%	77%	77%	55%
7	3	F	83%	100%	17%	60%	85%	25%	56%	78%	22%	22%
8	4	M	77%	100%	23%	100%	100%	---	100%	100%	---	23%
9	5	M	77%	100%	23%	100%	100%	---	87%	100%	13%	18%
10	5	M	100%	----	---	90%	100%	10%	90%	100%	10%	10%
11	5	M	77%	100%	23%	100%	100%	---	50%	100%	50%	37%
12	5	M	75%	100%	23%	83%	100%	17%	38%	77%	39%	27%

Table 2

Pre- and Post-test Results on a Sentence Imitation Task in Child's Best Mode of Communication

Subject	Age	Sex	Mode of Communication	Pre-test % Correct	Post-test % Correct	% Improvement
1	2	M	SC*	0%	19%	19%
2	2	F	SC	0%	26%	26%
3	2	F	SC	0%	24%	24%
4	3	M	ASL*	33%	73%	40%
5	3	M	ASL	0%	76%	76%
6	3	M	SC	22%	41%	19%
7	3	F	SC	0%	37%	37%
8	4	M	ASL	22%	87%	65%
9	5	M	SC	22%	26%	40%
10	5	M	ASL	100%	---	---
11	5	M	SC	0%	34%	34%
12	5	M	ASL	0%	54%	54%

*SC = Simultaneous Communication
ASL = American Sign Language

Both reading skills (and the associated skills of "writing" through key-pressing) and general language skills (as measured by imitation) were improved during the period of instruction for these deaf children. Extensions of the present exploratory work would appropriately compare these gains to efforts of alternative instructional programs for reading and writing. In addition, it will be important theoretically and practically to build in internal comparisons concerning the optimal presentations of the signs, pictures, text, and teacher input for facilitating deaf children's processing of the material and their acquisition of new reading, writing, and general communication skills.

Discussion

Initial results using this newly developed interactive approach to reading instruction with the microcomputer is beginning to demonstrate that deaf children as young as 2 years of age can acquire reading comprehension and decoding skills. Also, preliminary results are showing that this computerized instructional approach has an impact on stimulating general language skills. In addition, because the child learns in this approach to <u>create</u> appropriate printed sentences by his or her own actions (pressing word keys), aspects of writing are centrally involved. The results substantiate the notion that reading and writing need to be integrated within a system of exchange of information between children and teachers in order to be effective. When this integration is done in a thoughtful and balanced way, then it is shown that the children's motivation is greatly stimulated and that the children learn how powerful a tool written messages can be in expressing their own thoughts and in making contacts with other people. The contrast is an attitude of approaching reading and writing simply as a small set of pre-established programs or books that must be dealt with simply because teachers or parents have asked the children to spend time on these materials.

From the beginning in this project, the child sees that his/her own interests and ideas are reflected in the materials presented on the computer and that they can initiate messages as well as respond to printed material that others have chosen.

There is little doubt that hearing-impaired children generally have intact cognitive skills, yet fail to achieve comparable general communication skills or comparable reading and writing skills that match corresponding skills for hearing children of similar intelligence or cognitive ability. By working with young children to establish both early reading and writing skills and to enhance general communication skills, there is a strong possibility that a solid base can be established for the hearing-impaired child's progress generally through the educational system. Every source of information available now indicates that most hearing-impaired children are not receiving effective instruction in reading and writing and communication skills, and that because these skills are deficient, they are also not reaching high levels of achievement in most academic areas. The research described above has a strong potential for impact on the education of hearing-impaired children because from the beginning of supplemental instruction it takes seriously the integration of reading and writing into general communicational exchanges and emphasizes the individualization of instruction for children.

The present study involved redundant presentation of messages selected by the pupil: for example, upon pressing the keys "Dog," "Eats," "Cookie"--the child saw on the TV screen text plus picture animations plus sign animations. Assuming that one central goal of the instruction is the acquisition by the child of new connections between text words or text sentences and meanings to which the child already has access before instruction, then there are many interesting theoretical questions that could be addressed through variations on the present interactive

theme. For example, are some deaf children better processors and learners when only sign and text pairings occur in initial introduction of new textual information? Are other children more efficient learners if text-picture associations are mastered before any emphasis is placed upon sign? A related question is how much the language interactions with the teacher enhance the learning of new text meanings and enhance the incorporation of these new text interpretations into the classroom and other situations where new text variants (e.g., books and other types of printed material) are presented? Moreover, the processes by which demonstrated advances in general language skills contribute to more rapid acquisition of text-related skills will be a topic of keen interest. In sum, at the theoretical level as the research is extended and refined, it will be possible to learn much about how different input combinations are used by deaf children in the acquisition of new reading and writing skills and new skills in using language in nontext modes.

In addition, future assessments will include memory and specifically reaction time measures of text, sign, and pictorial messages. This type of research should contribute to an understanding of the extent to which written English vocabulary and sign vocabulary are coded categorically into short-term and long-term memory by deaf children. Also, it should provide important information on the extent to which textual material is translated into a manual-based code for storage in memory. This research may offer further insights into the role of reading comprehension as a generative process involving the actual construction of meaning for written language by relating it to previously acquired knowledge and memories of experience. Future research should focus on variations in cognitive styles, information-processing, and individual differences in relation to reading, writing, and general communication.

The overall significance of this research lies not only in testing a new cognitive approach to reading and writing for deaf children but also in the later educational options that would be opened by early success in reading instruction. In sum, the research is attempting to minimize, through a new form of early cognitive training, many of the adverse social and educational consequences which have been too often associated with congenital or acquired deafness.

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APPENDIX

Initial Reading Instructional Sequence

The instructional approach outlined in the method section was employed during the first year of the study. The OMEGA and ALPHA Language/Reading series are used to develop basic competence in interactive reading and writing instruction both for the classroom teacher and the child. The instructional procedures with these programs is described below.

The teacher begins with a presentation of basic reading vocabulary contained in the "Learn Lesson" (LL) section of OMEGA Lesson 1. LL is presented twice and then the teacher proceeds to the "Test Lesson" (TL) where the vocabulary items from LL are presented in random order. In TL the student is presented with a picture of an object (nouns) or an animated figure representing an action (verb). On the sign language version of the program, the computer also presents an animated version of the graphic representation of the sign. TL is repeated and if the child attains criterion level of 80% accuracy, the teacher moves to the "Sentence Structure" (SS) lesson.

If the child does not reach criterion, TL is repeated two additional times. In SS, the child has the opportunity to create short phrases and sentences with vocabulary previously learned in LL and then observe the animated sequence on the TV screen (either with or without animated signs as needed). SS is presented three times.

If the child experiences difficulty, TL (and if necessary LL) are repeated. At the point where all possible sentences have been created on SS and the child readily responds to the teacher's questions using SS vocabulary, the child can proceed to OMEGA 2, the next lesson in the series. Additionally, the OMEGA series provides the teacher and student with special interactive communicative options

(e.g., the teacher can type in a message with the option of having it appear on the screen or only on the printout of the session).

After completing OMEGA Lessons 2 and 3, the child is ready to begin the ALPHA series, which is a companion to the OMEGA language lessions. The ALPHA lessons allow the student to produce simple sentences using vocabulary learned from the OMEGA lessons and some new vocabulary words introduced in the ALPHA lessons. Each ALPHA microcomputer diskette contains 10 "packages" containing up to 10 individual lessons each. Each lesson presents new vocabulary items. Some packages are prepared with fully structured lessons, while others are only partially completed to allow the teacher and/or student the opportunity to design lessons to be saved on the diskette. The ALPHA lessons contain two primary sections: Creating Sentences (CS) and Testing Sentences (TS). With the CS session format, the child can create sentences from the vocabulary presented in the selected lesson. The child simply presses the keys for a noun-verb-noun sequence and waits briefly for the animated sequence to appear on the TV screen (as with the OMEGA lessons, animated sign sequences are optionally displayed by the computer). After an entire sentence has been animated, the child or teacher have the option of replaying the animated sequence or activating the sign language representation of any of the words in the sentence. The speed of the animated graphic representation on the screen as well as the duration of the sequence on the screen can be controlled by the paddles attached to the microcomputer. The ALPHA CS lesson is repeated, and then the teacher can switch to the TS (test) format to assess the child's level of competence in producing sentences. In the TS section, the computer generates an animated depiction of a noun-verb-noun sequence randomly selected from the vocabulary in the ALPHA lesson. After the animation has been completed on the TV screen, the child selects the corresponding noun-verb-noun sequence on the EXPRESS keyboard.

After a noun-verb-noun sequence has been tested, the student's score is automatically computed and the test items and score printed. TS is repeated until mastery level of 80% on two consecutive tests is reached. The entire instructional sequence is repeated for subsequent OMEGA AND ALPHA lessons with new vocabulary and new sentences. Then open-ended writing and message-exchange lessons are introduced for advanced students. In this advanced level of communication exchanges, as in each step that precedes it, the teacher is an active and supportive part of instruction.

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